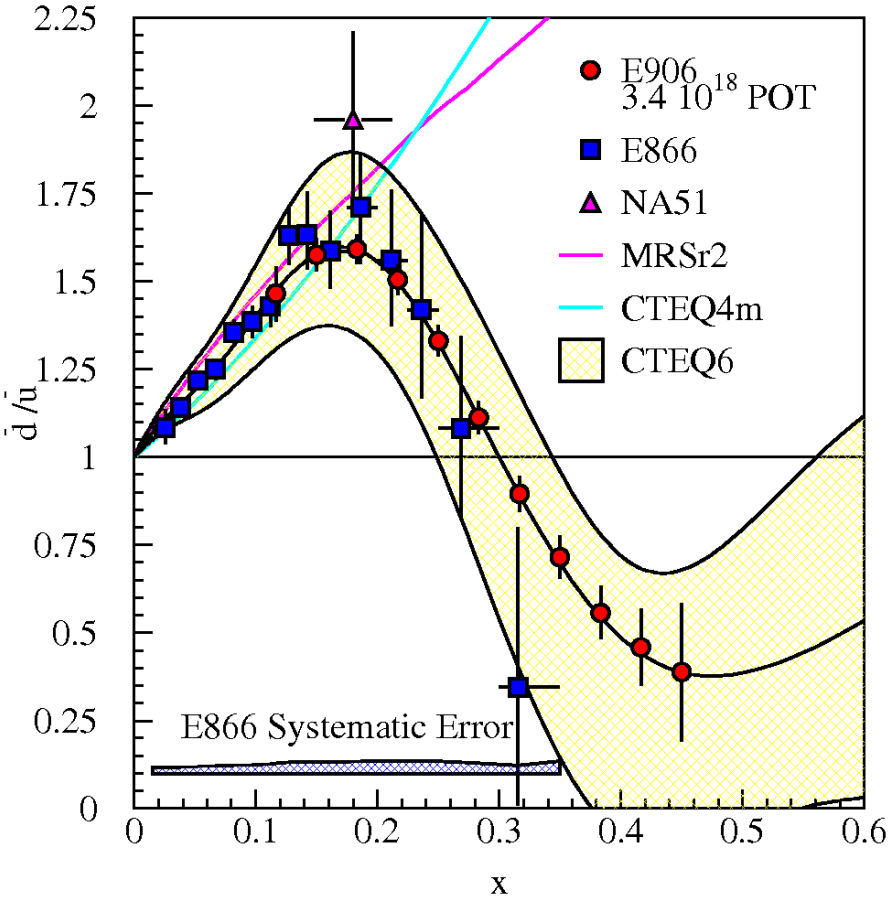
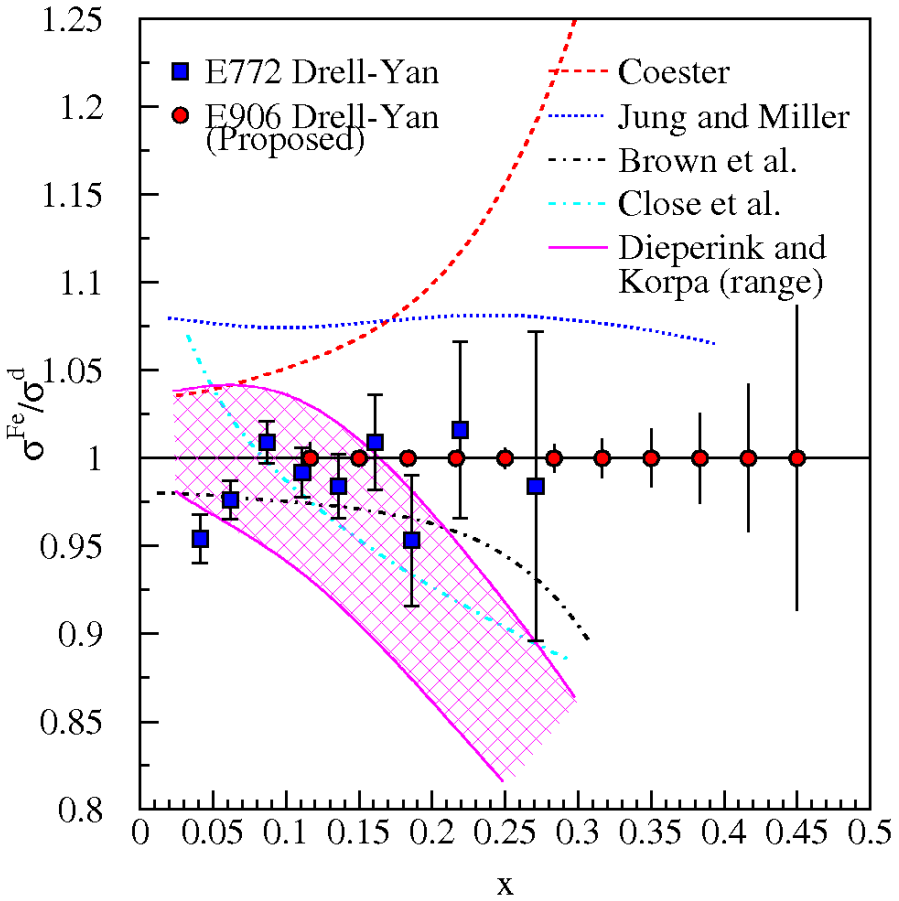
E-906/SeaQuest: Experimental Management Group

Paul E. Reimer
Argonne National Laboratory
9 August 2013

I. Physics Overview
II. Review of 2012 Commissioning
III. Beamline progress
IV. Spectrometer Upgrades
V. Computing and Analysis

SeaQuest: the quark sea in the nucleon and nuclei





Drell-Yan gives access to sea quark distributions

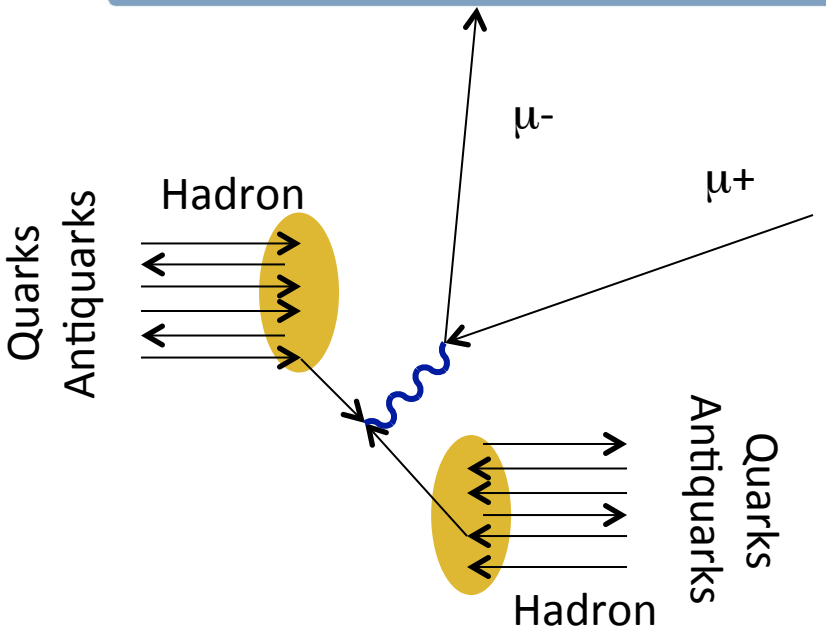
- Measured cross section is a convolution of beam and target parton distributions
- **Proton Beam**
  - Target antiquarks and beam

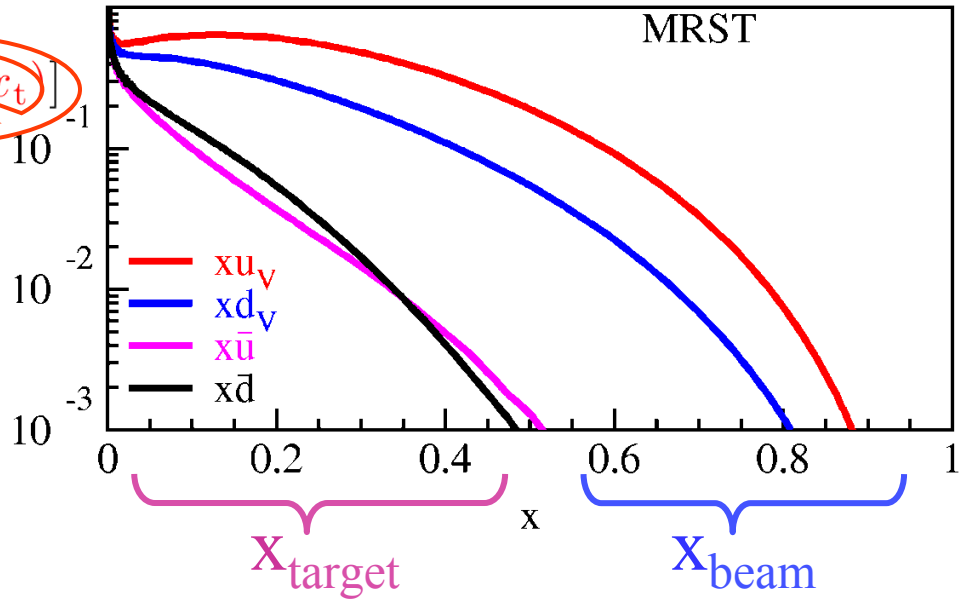
$$\frac{d^2\sigma}{dx_\mathrm{b}dx_\mathrm{t}} = \frac{4\pi\alpha^2}{x_\mathrm{b}x_\mathrm{t}s} \sum_{q\in\{u,d,s,\dots\}} e_q^2 \left[\bar{q}_\mathrm{t}(x_\mathrm{t})q_\mathrm{b}(x_\mathrm{b}) + \bar{q}_\mathrm{b}(x_\mathrm{b})q_\mathrm{t}(x_\mathrm{t})\right]$$

Acceptance limited

- u-quark dominance

  $(2/3)^2$ vs. $(1/3)^2$ × (2 quarks vs. 1 quark)



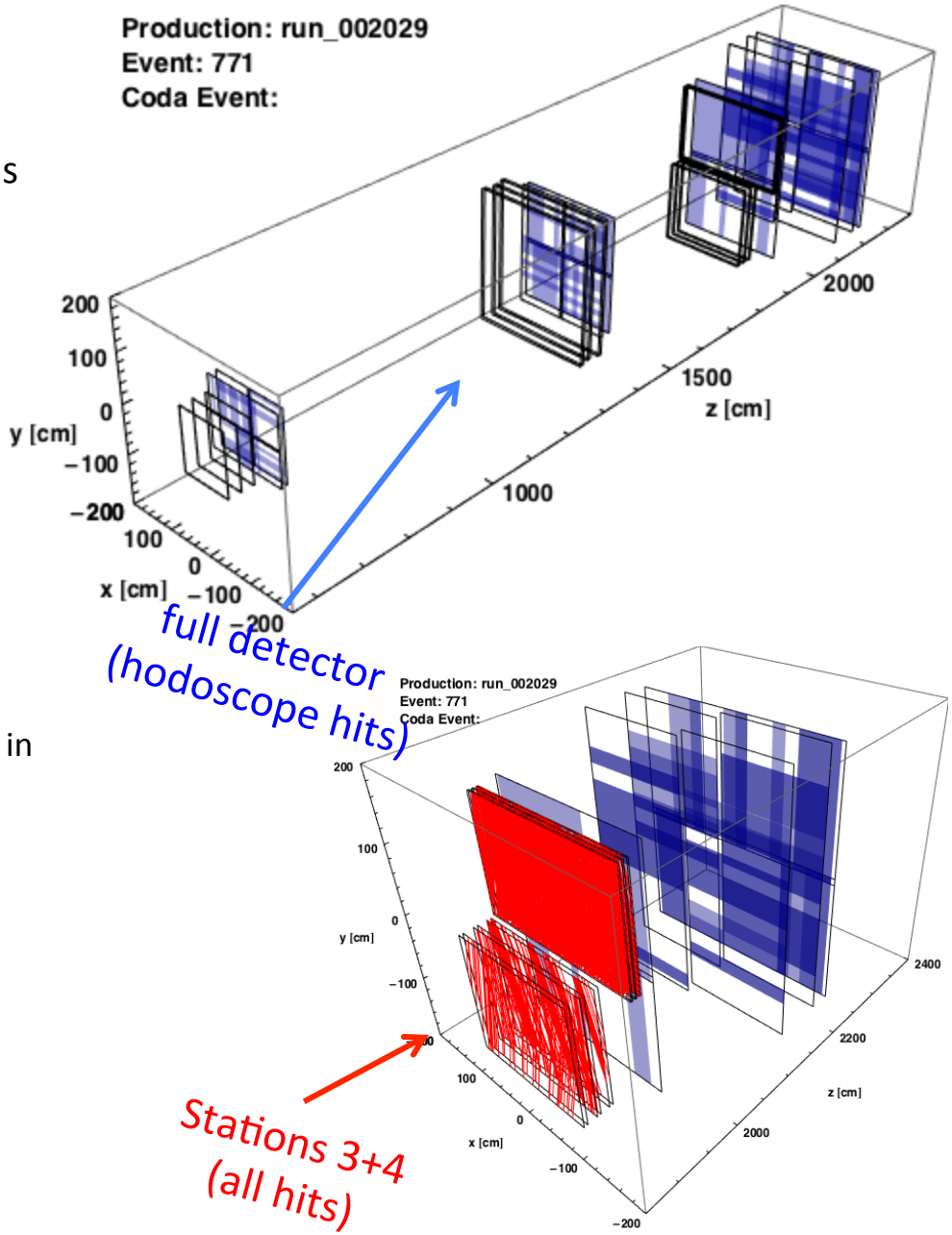


Commissioning Run 2012

- Brief 2-month run after many interesting diversions
- Commissioning for both Spectrometer and Accelerator

- Accelerator:
  - Large intensity variations within spill
  - vacuum in berm pipe

- Spectrometer:
  - DAQ TDC firmware not quite ready
    - Lacked hardware zero suppression (zero suppression in front-end CPU)
    - Large dead times, especially with large events
  - PMTs at St. 1 need better rate capabilities
  - Interim St. 1 and 3- Tracking



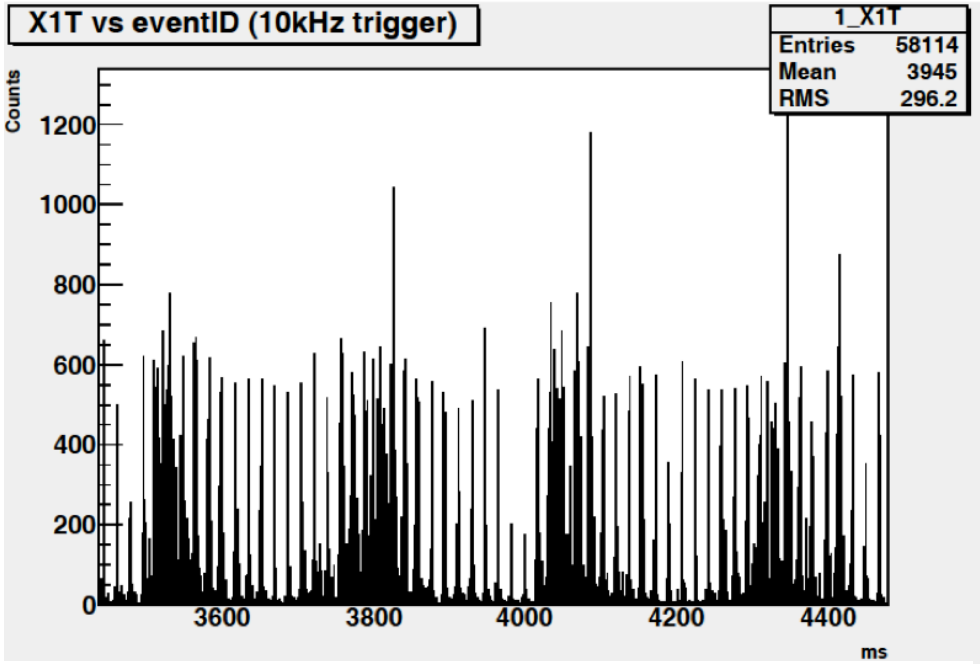
Commissioning Run

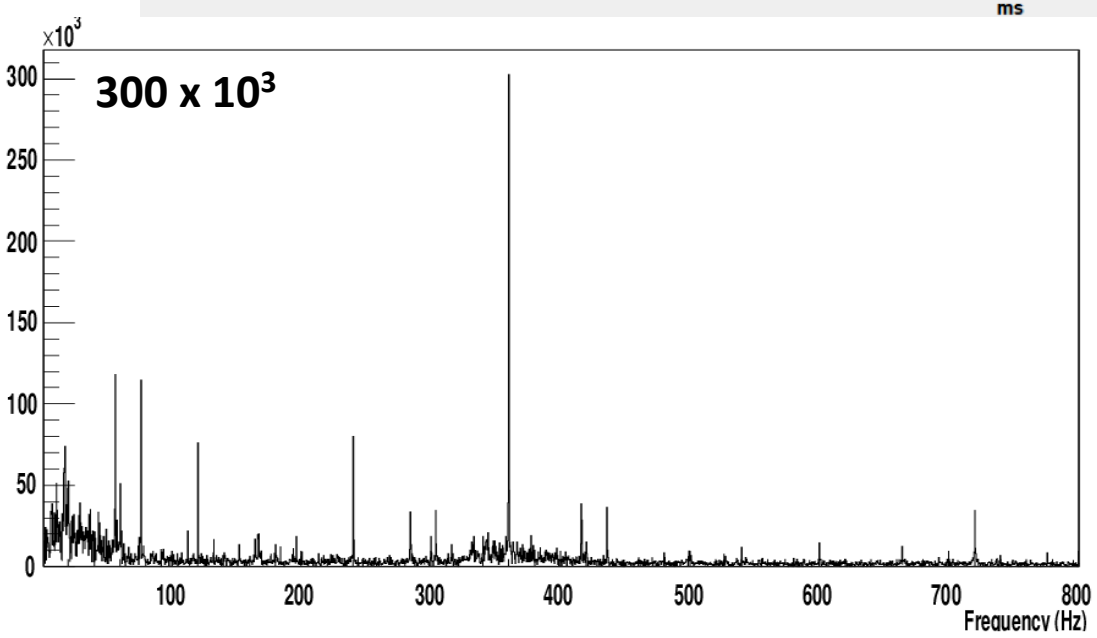
- *Average* intensity normal, measured by beam line instrumentation
- Independent 10kHz pulsed DAQ read out raw hodoscope rates
- Bins are integrated counts over 100μs (≈5000 RF buckets)
- Large variation in Instantaneous intensity, duty factor very low.
- Periodic structure—Phase locked to AC 60 Hz

Conclusion:

The MI extraction was also being commissioned.

AD believes that these problems have been addressed.



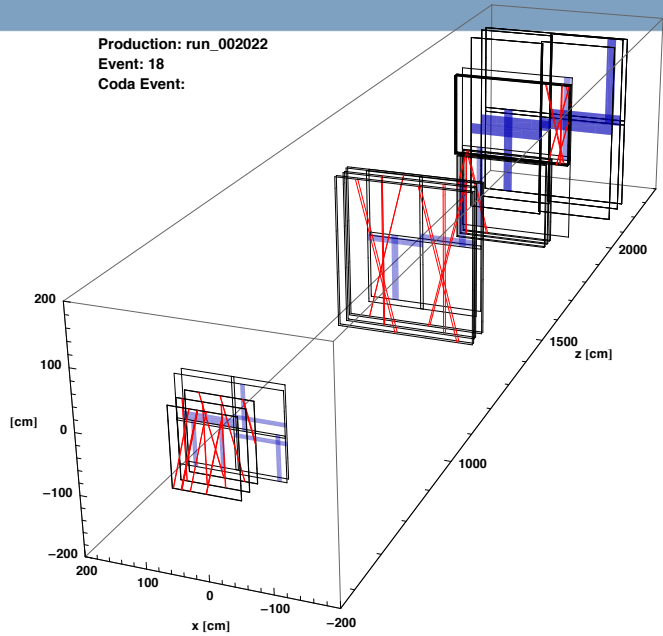


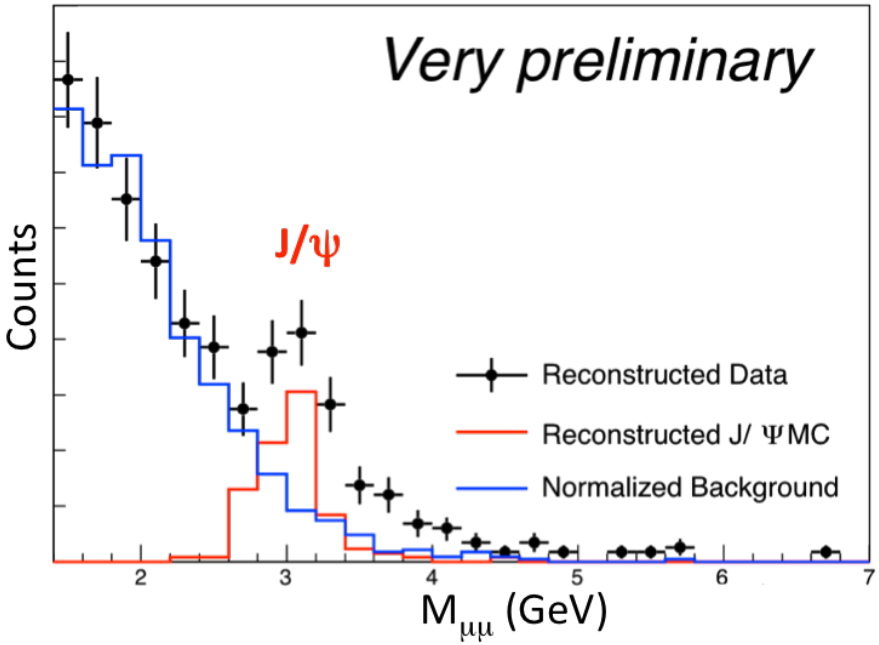
Commissioning Run Data

- "Splat Block"
  - A card was developed to keep a running average of the multiplicity over a 160 ns window (8 RF buckets).
  - If average multiplicity above threshold, raises a trigger veto

- Analysis
  - Noisy data was hard place to start
  - Developed and tuned track finding and fitting under "worst case" beam conditions.
  - Develop internal alignment procedures

- Hardware
  - Pointed to areas in need of improvement





Shutdown Activities

Targets:

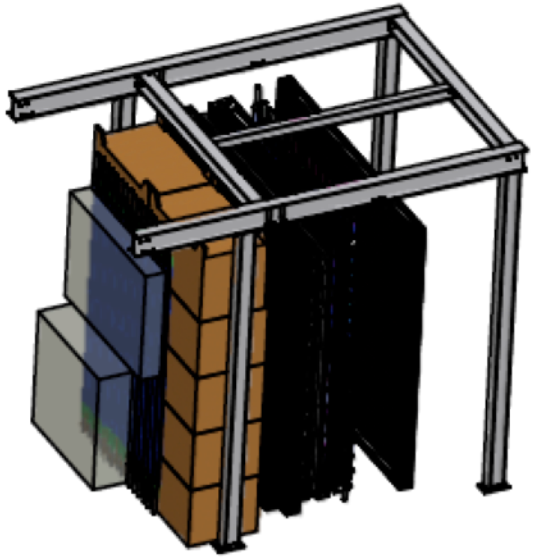
- iFIX on Target Computer (Windows 7)
- Spare flasks under construction

TDC Micro Code

- Write
- Full system test with beam

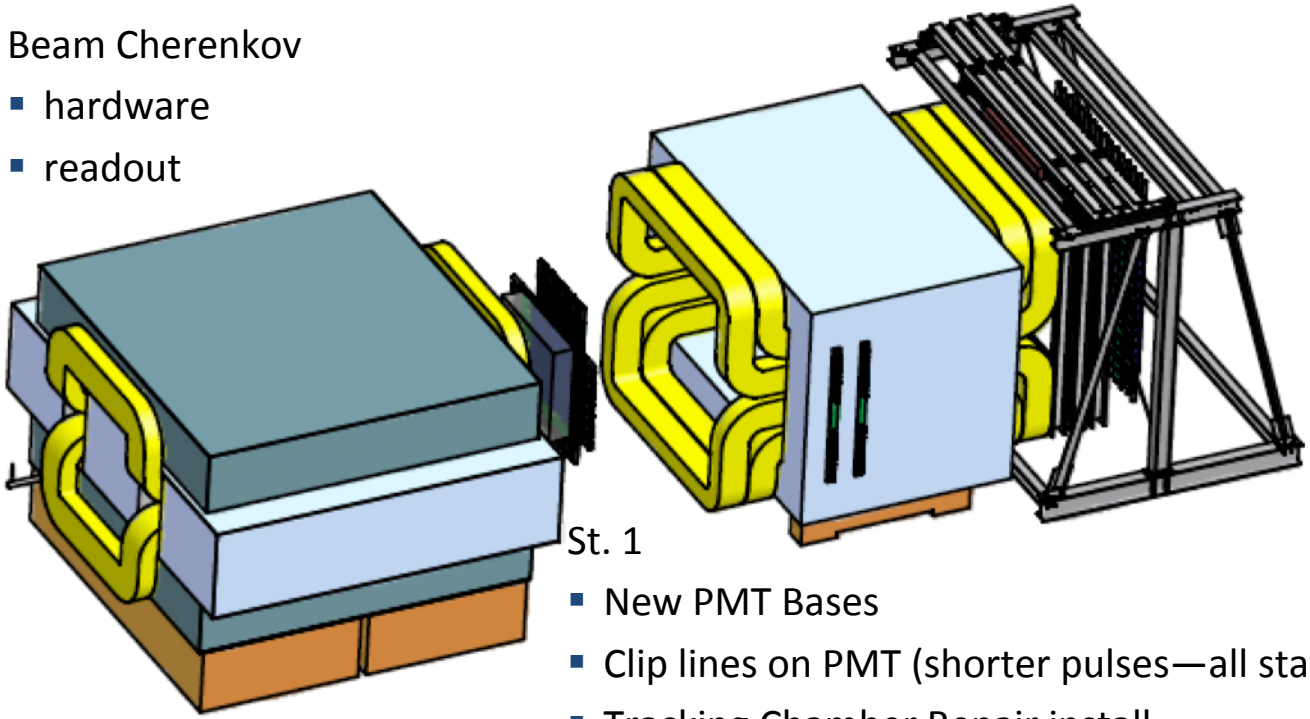
St. 4:

- Service beam



Beam Cherenkov

- hardware
- readout



St. 1

- New PMT Bases
- Clip lines on PMT (shorter pulses—all stations)
- Tracking Chamber Repair install
- New Chamber

St. 3:

- Reinstall St 3+
- Complete and install St. 3-

Magnets:

- Neutron Wall
- Power test in March

St. 2:

- New PMT Bases

DAQ:

- Integrate new TDC
- Cherenkov Setup

Shutdown Activities

~~Targets:~~

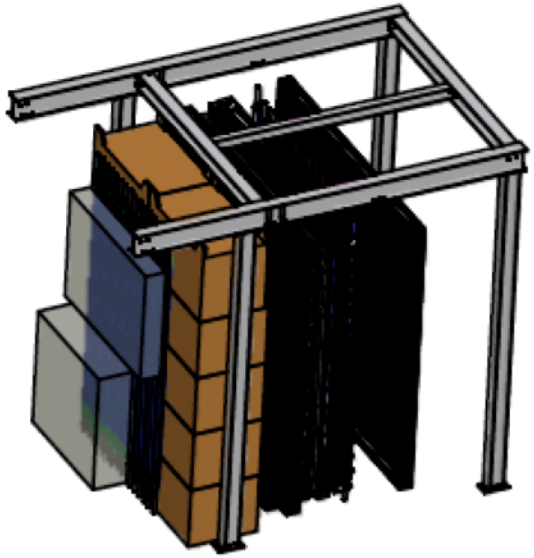
- ~~iFIX on Target Computer (Windows 7)~~
- ~~Spare flasks under construction~~

TDC Micro Code

- ~~Write~~
- Full system test with beam

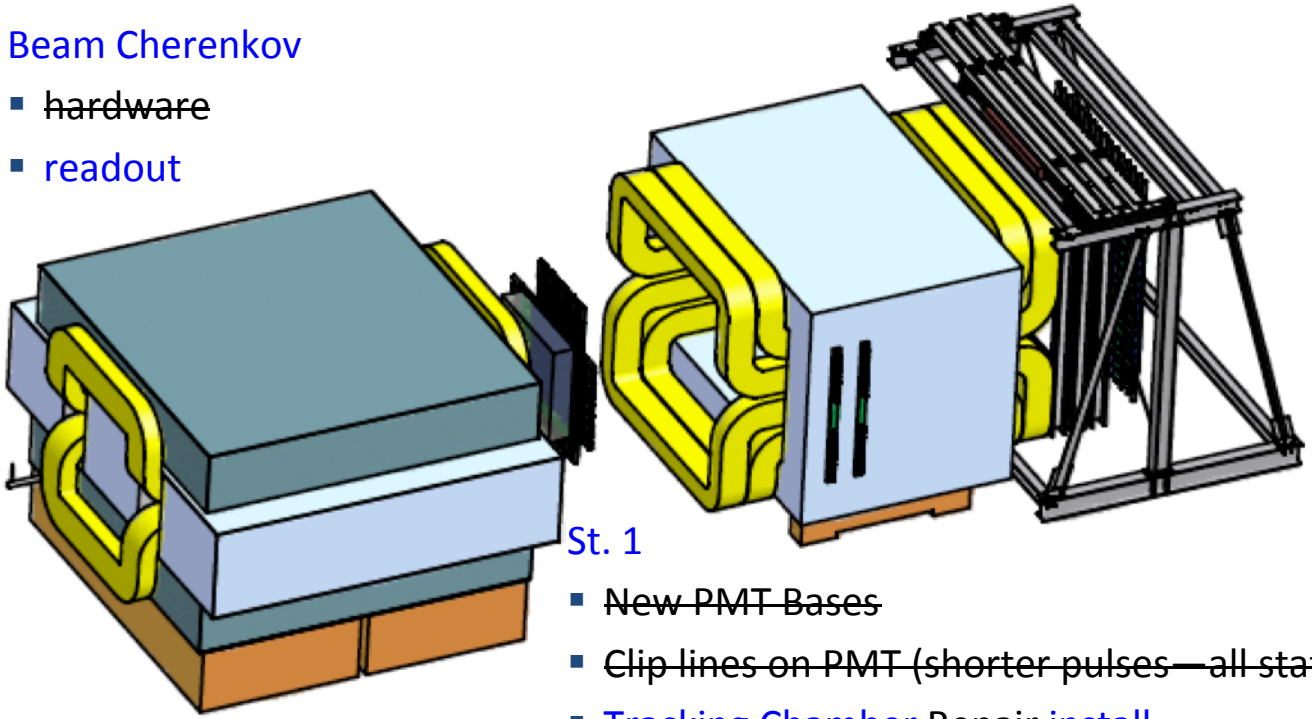
~~St. 4:~~

- ~~Service beam~~



Beam Cherenkov

- ~~hardware~~
- readout



St. 3:

- ~~Reinstall St 3+~~
- ~~Complete and~~ install St. 3-

St. 1

- ~~New PMT Bases~~
- ~~Clip lines on PMT (shorter pulses—all stations)~~
- Tracking Chamber ~~Repair~~ install
- New Chamber

~~Magnets:~~

- ~~Neutron Wall~~
- ~~Power test in March~~

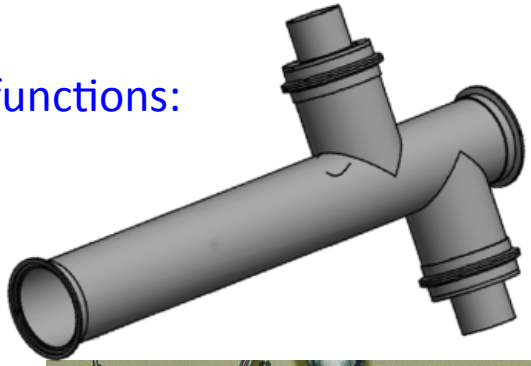
DAQ:

- ~~Integrate new TDC~~
- Cherenkov Setup

~~St. 2:~~

- ~~New PMT Bases~~

Beam Intensity Monitor



N_2 Cerenkov Counter upstream of the targets. Three functions:

- Instantaneous Luminosity—Event readout
- Duty Factor
- Spill readout
  - At end of spill, output entire spill record + total intensity, intensity while DAQ dead, record of splat block. Feedback for MCC (used to produce FFT)
- "Splat block"
  - Compute circular sum of beam intensity
  - Inhibit triggers if sum>threshold

Readout

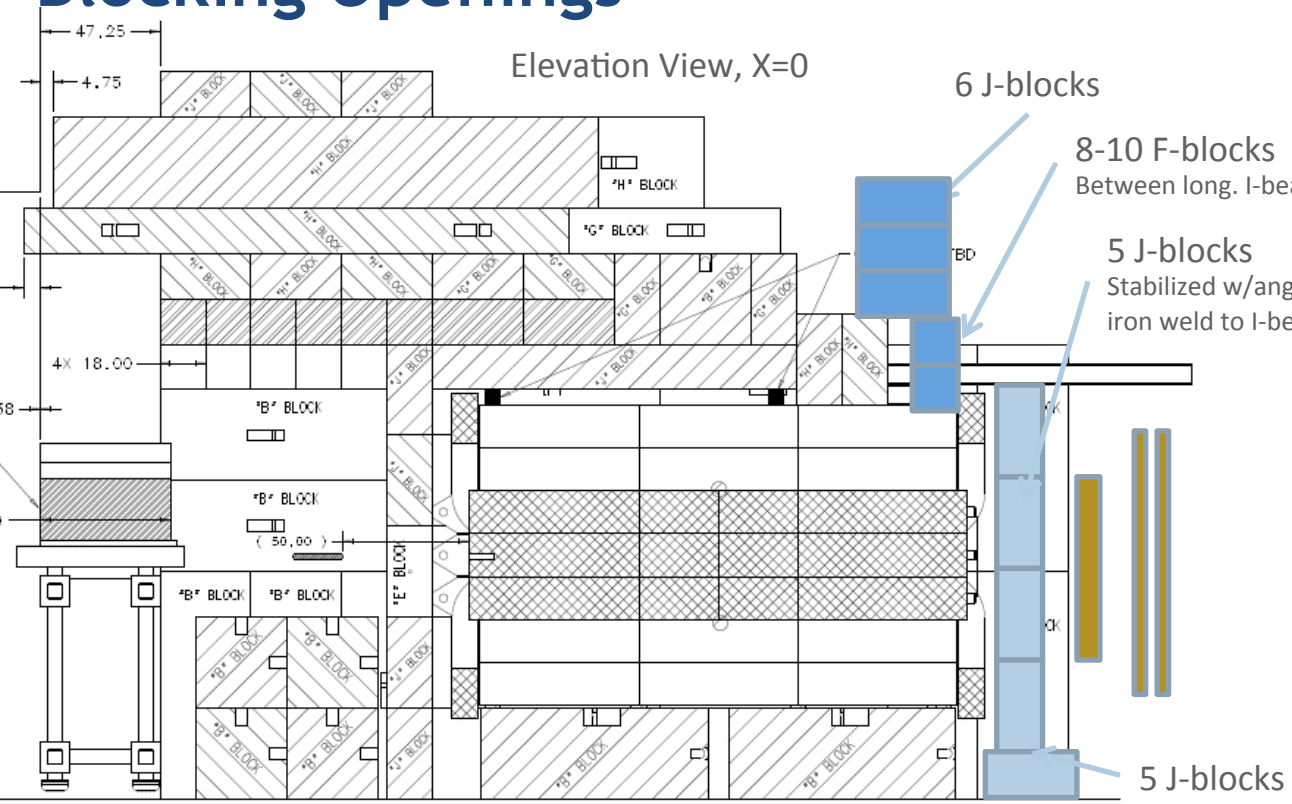
- Digitization by a QIE-10

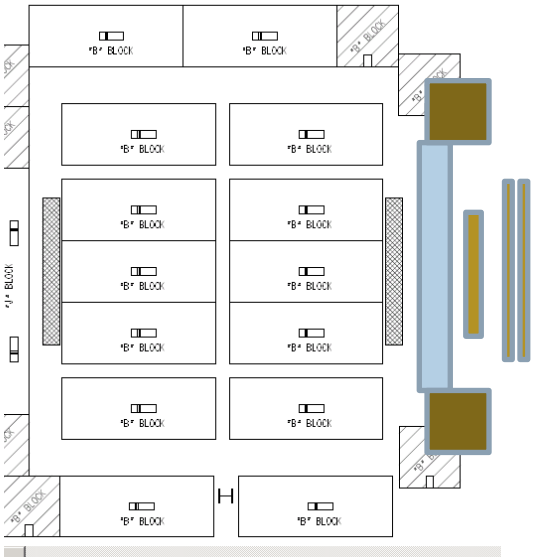
Beam Testing

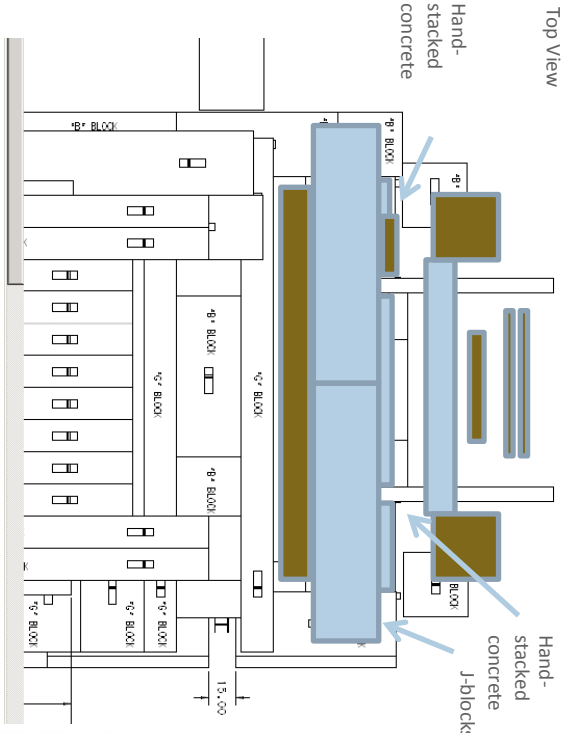
- Would like to have fully functional readout by time beam arrives at NM4
- **FTBF parasitic test—requires MCC to tune beam to FTBF for maximum duty factor—likely needs more than 10-50 rf cycles full.**

Thanks to AD/Mike Geelhoed

Blocking Openings







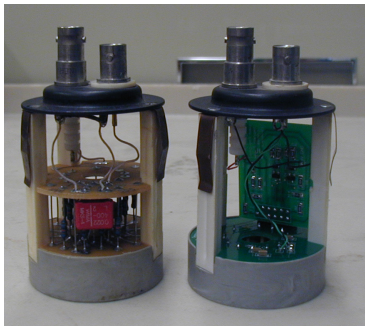
Reduce Random hits at St. 1

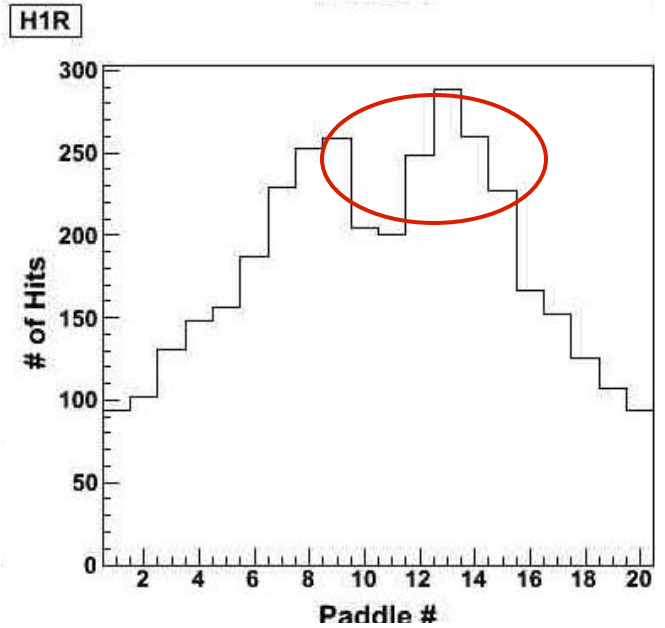
- Wall is done

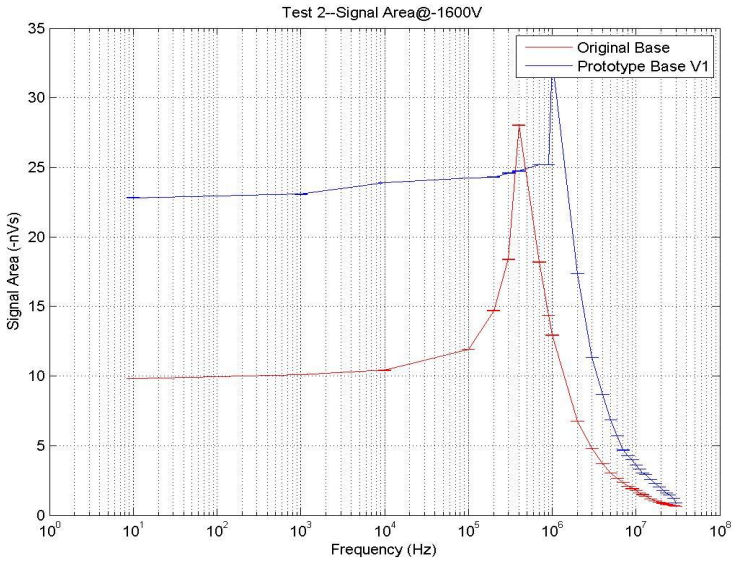
Thanks to PPD/John Vorin

St. 1 & 2 Photomultiplier bases

- Drop in performance in high intensity & rate hodoscopes
- Destabilization of voltage diff. over latter dynode stages
- Solution: New PMT base
  - Higher supply current draw
  - Voltage stabilization features
- Results:
  - 3x rate improvement
  - 2x amplitude improvement
  - Able to bypass amplifiers in DAQ
- Status:
  - all bases installed
  - gain matching w/cosmic
- Clip lines
  - Installed on all bases (St. 1-4)
  - reduce pulse width (as expense of some signal)





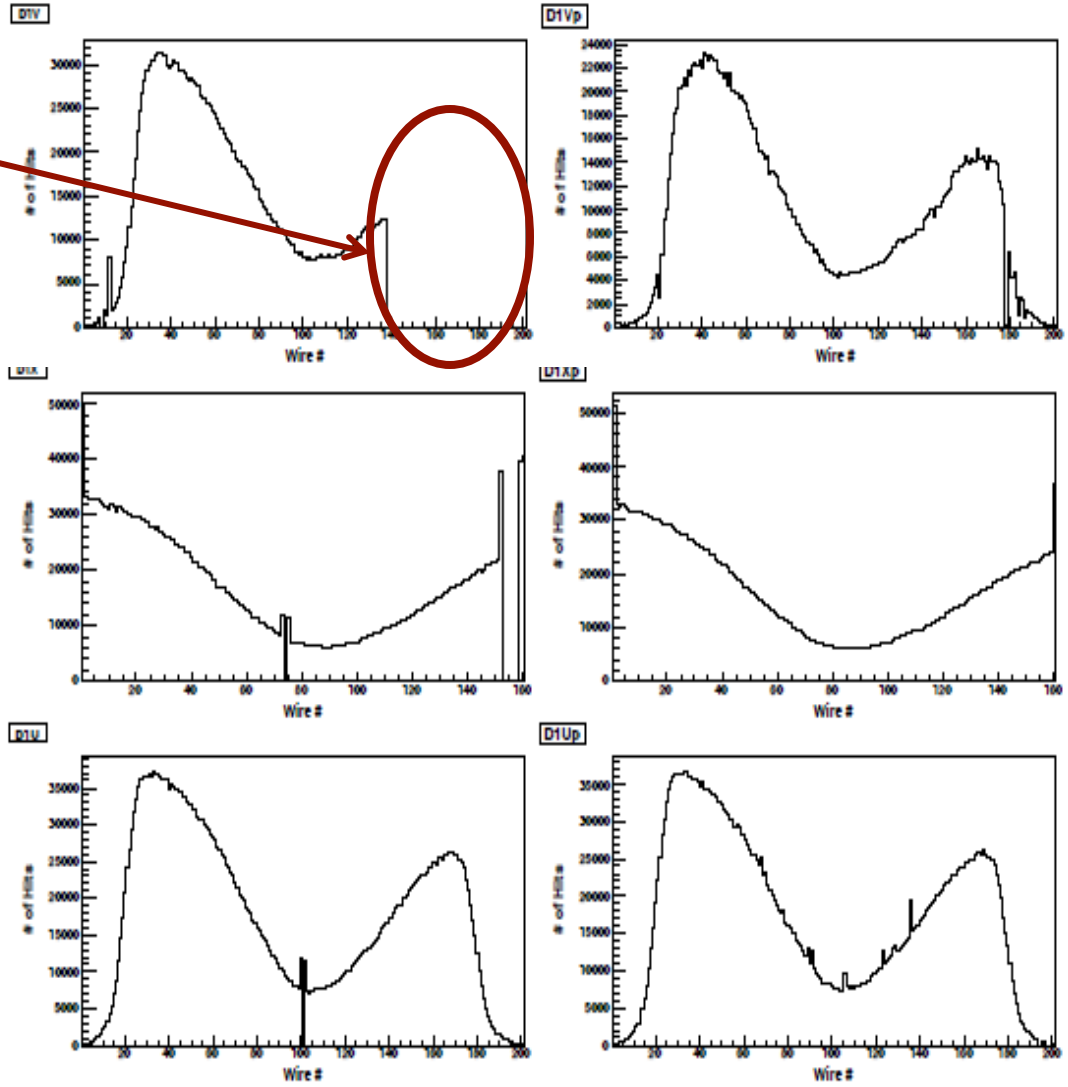


Old St 1 Tracking Repair

- Third of the D1V plane was dead.
- Two identical sense planes; D1V and D1Vp. No half drift cell shift between them.
- Two wires of D1X and one wire of D1U accidentally broke during Run I
- During repair accidental overpressure of D1X gas windows caused rip and broken wires.

- All items repaired
  - D1V installed,
  - D1X to be installed next week
  - followed by D1U

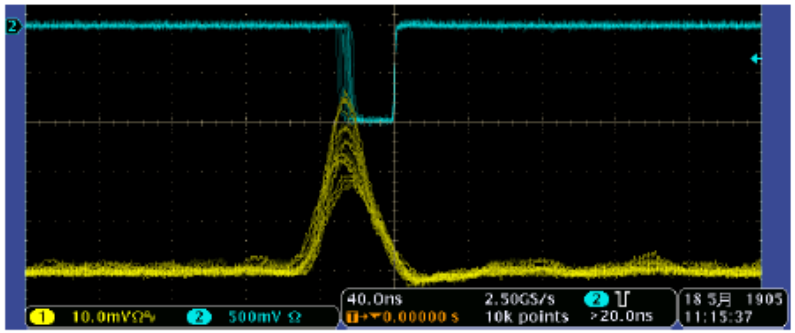
St1 Hit Distributions (run 2173)



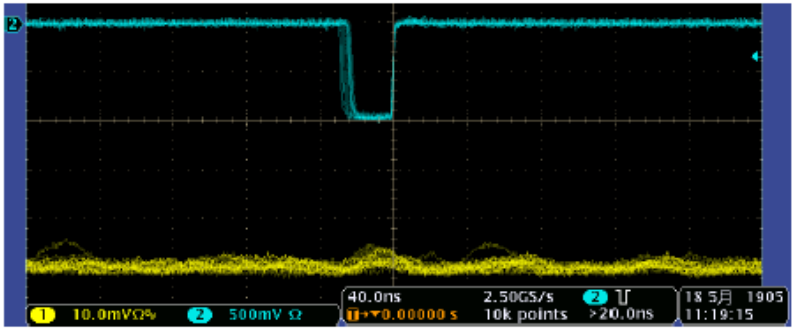
Thanks to PPD/Wanda Newby

Tracking St. 3+ Cross Talk

- Signal
  36 mV



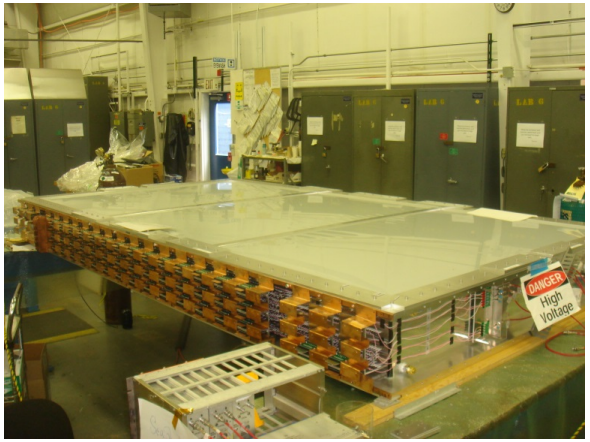
- Crosstalk
  4 mV (10%), later by 20 ns

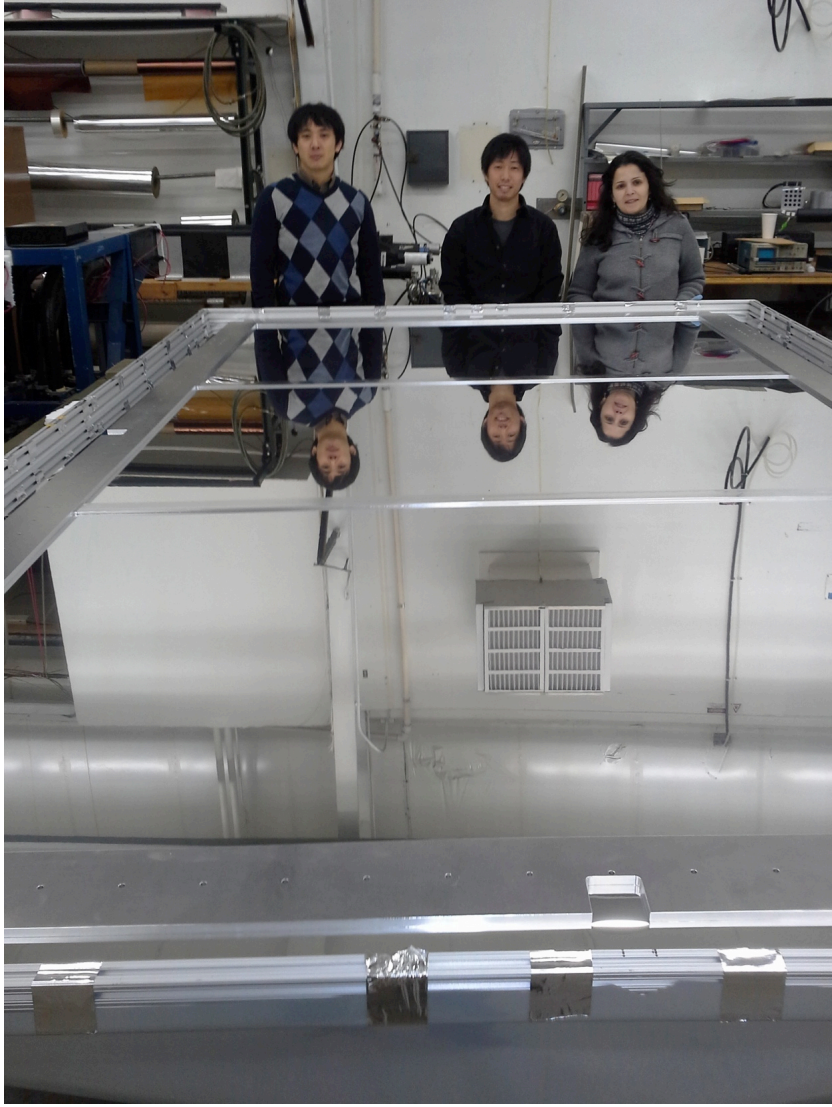


- Timing and simulation showed that cross talk was from a reflection due to impedance mismatch at end of wires
- Simplest solution was to move the HV bus on the chamber
- Verified with test-chamber and source at Tokyo Tech
- Modifications **complete** on St. 3+ at SeaQuest Hall

Tracking station 3-

- Construction work
  - Duplicate of St 3+
  - Assembled at Fermilab Lab6.
  - All the amplifier card and noise-shielding parts were attached.
- Status
  - HV is on, and currents are very low and stable.
  - Transported to the SeaQuest hall in early July.
  - Installed to the spectrometer in a week.





Thanks to PPD/Wanda Newby

TDC Microcode Upgrade

Background:

- SeaQuest uses a custom FPGA-based VME module for all DAQ—Academia Sinica
- Modules may be programmed in many ways. SeaQuest using them as a multi-hit TDC
- Microcode **for commissioning run**
  - off board 0-suppression (extreme dead times)
  - 2.5 ns resolution (Not great, but OK for required resolution)

The development and production test of Run2-TDC were done at April.

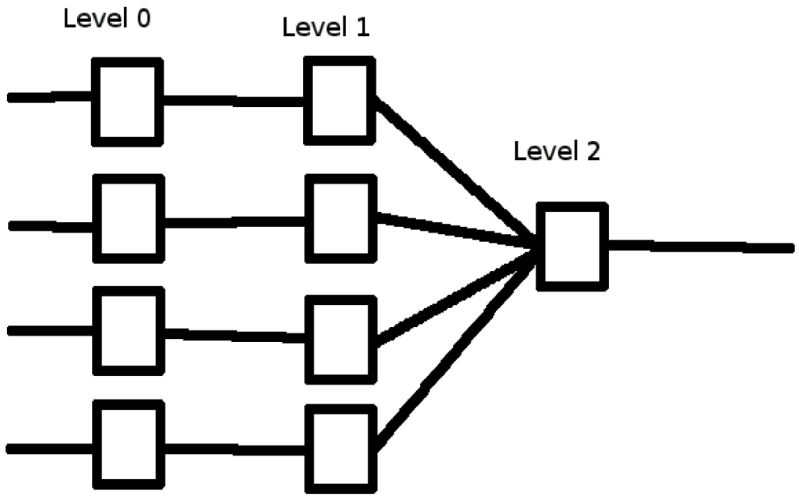
The Run2-TDCs for Hodoscopes and Proportional tubes have been implemented in E906DAQ system and tested.

Run1-TDC v.s. Run2-TDC		
	Run1-TDC	Run2-TDC
Zero Suppression	None	Naturally applied
Time Resolution	2.5 ns	~0.44 ns
Minimum width of signal	10 ns	4 ns
Maximum number of hits in 64 ns	6 hits	4 hits
Width of accepted window	Adjustable: 320 ns or 640 ns	Adjustable: 4 – 2048 ns in a 4-ns step
Edge detection	Both Edge	Adjustable: leading edge only or both edges.
Maximum number of hits per trigger	Record all hits within Tine window	Adjustable: 32-1024
Maximum numbers of events per IRQ	1	Adjustable: 1-32
Scalar buffer to record # of hits each channel	None	8
Multiple Hits Elimination	None	Adjustable: Disable time window (16 -272)

E906 Run 2 Trigger

New Trigger Hardware Setup:

- 4 new v1495s make 'Level 0'.
- Level 0 records all hits with internal TDC.
- Level 1 and 2 contain all trigger logic.



Other changes:

- New trigger for 'same-side' dimuons (both muons in the same half of the spectrometer). Better acceptance for angular analyses.
- Bend-plane meantimers removed.
- Automation of firmware upload chain; less prone to human errors, better documentation of changes to trigger.

Comprehensive pulser test:

- Test input handling, TDC hit recording, and logic of trigger firmware.
- Goal: Done by August 22nd.

DAQ

Background:

- CODA system written and maintained by JLab
- 2 separate systems
  - Event DAQ (or Main DAQ)
  - Scaler DAQ for beam monitoring

Main DAQ

- New event format from TDC micro code

Scaler DAQ (feedback to Accelerator on duty factor)

- Added additional scalers (not a significant change)
- Readout of Cherenkov Beam Intensity Monitor

All DAQ activities over a private (192.168.xxx.) network

Raw Data Storage on Fermilab STKEN Enstore & RAID in counting house

Processed data on MySQL server at UIUC & counting house

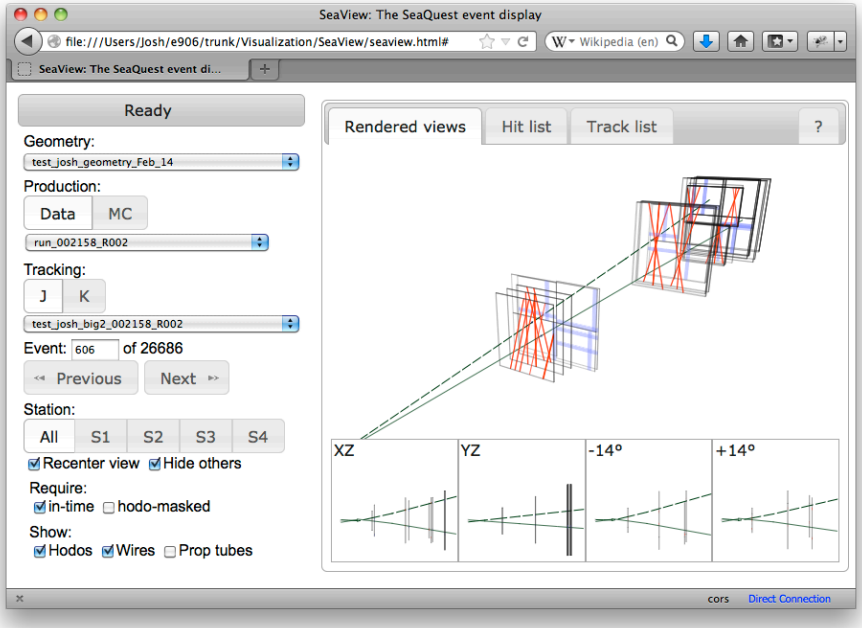
Data Storage and Processing

- Depends significantly on beam quality
- w/excellent beam quality, E866 give lower limit of 5 TB raw data
- Currently we have approx. 40 TB of data space at SeaQuest.

Run I (03/07/12—04/30/12)	Run II (two years)
1TB of raw data	→ 12 TB of raw data → stored on dCache and local RAID
→8TB of MySQL data productions →file size dominated by hit information	size ++ Higher event rate size-- more compact format → 10 TB of MySQL data → storage on FNAL and UIUC servers
→real-time decoding	size ++ Higher event rate size-- Store less Information real-time decoding online tracking on sample full reconstruction on Grid

Online Visualization

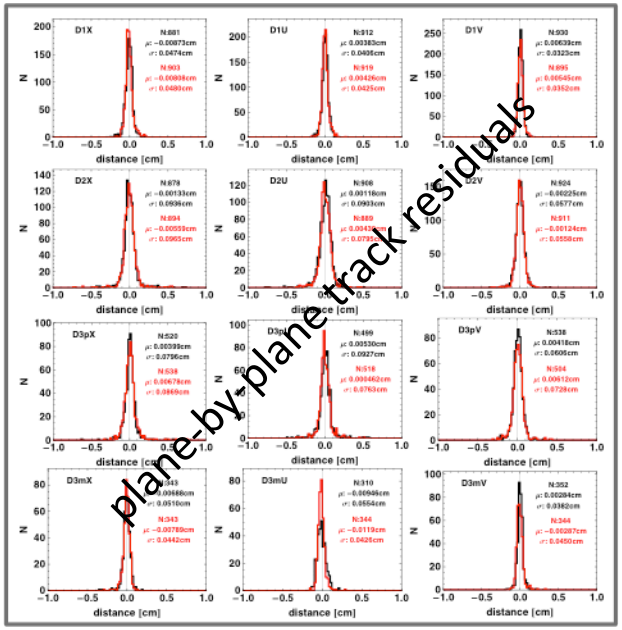
- Server:
  - manages MySQL server communication in a a robust way
- Client:
  - multithreaded web application, highly modular and extensible backend
  - modern interactive web application using the latest technologies: HTML5, CSS3, Javascript/ES5

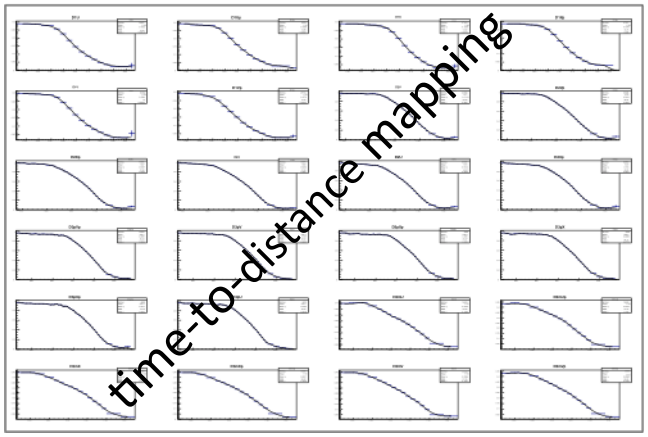


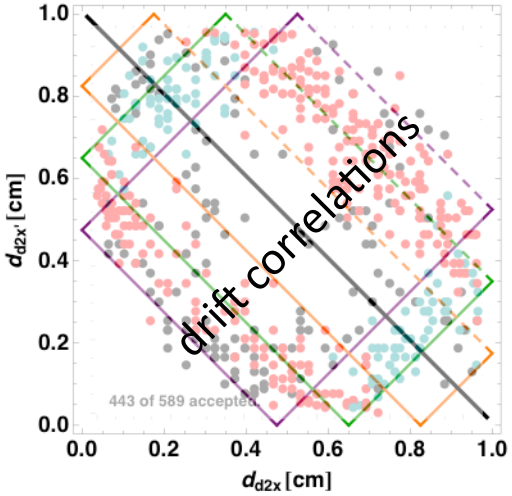
- Event Display
  - New browser-based event display software developed

Offline Software Status

- Geometry and alignment from Run I well understood. Alignment procedure established
- Chamber calibrations from Run I complete







Event reconstruction (track finding and and fitting) being optimized.

- Currently ~5 events/CPU second.
- Suitable for quick on-line feedback (what did the last spill look like?)
- Dominated by combinatorics (duty factor)
- Offline—grid computing

Commissioning Plans—same plans as March-April 2012

1 During Vacuum Repair

A. **Study beam duty factor with test beam, Work with MCR to improve diagnostics**

B. Operational Readiness Clearance (ORC)
   - **Will require engineering support for cross check of engineering notes**

C. Extended DAQ tests
   - Cosmic, source and pulse injection triggers

D. Geometry and alignment checks
   - **Measure as built**

E. Hodoscopes
   - Cross Check Hodoscope and Trigger Mapping (once again)
   - Gain match tubes (with cosmics)

H. Trigger

i. Sync timing of all triggers (v1495, NIM)—final timing with beam

Commissioning Plans with Beam

- Beam tuning
  - 1 booster batch and minimum intensity
- Spectrometer Commissioning
  - Follow same plan as March 2012
- Trigger studies: minimum intensity at highest duty factor
  - 6 booster batches of 84 bunches and 1 turn (How many protons would this be?)
    - 2012 run was 6 batches of 39 bunches and 1 turn to give 1×10^{12} protons/spill
- Special runs:
  - dedicated runs at high duty factor and lower intensity when FTBF is not running by changing the split to put 90% of beam on main beam dump—study rate effects
- As we validate trigger and detector performance, slowly increase beam intensity with goal of 1×10^{13} protons/spill
- Foil Activation/Beam Intensity calibration
  - When?
    - Worry about access/activation of target area
    - Need for stable well tuned beam
  - Poorly done in commissioning run

Run plan specific

Josh Rubin: Czar of "I wish we had taken xxx data in commissioning run"

A. Beam Cherenkov
   - PMT signal and voltage
   - 3 readout modes
B. DAQ commissioning in parallel with all work
   - I would be ecstatic if it worked perfectly, but. . .
   - Priority determined by Commissioning Team and Spokespersons
C. Scintillator Gain Checkout
   - Hodoscopes as function of voltage or threshold (need CAMAC controller)
   - **efficiency calculation** using well-tested hodoscope tracking, requiring KMAG off and so decoupled from wire-chamber commissioning determine thresholds to optimize efficiency
   - re-gain-match PMT (to get rid of NIM amplifiers)?
   - monitor efficiency (poor man's gain-monitoring)
D. Scintillator Timing
   - In parallel with gain, but must check after gain measurement
E. NIM trigger timing (in parallel with FPGA trigger timing)
F. FPGA Trigger timing (in parallel with NIM trigger timing)
   - Both need reasonably stable scintillator timing
G. Wire Chambers (in parallel with Hodoscopes as much as possible)

Major Concerns

1. Working Beam Line

2. Extracted Beam Duty Factor

3. Trigger Selectivity—heavily dependent on (2) duty factor

4. Improved offline reconstruction speed—dependent on (3) and (2)

5. Effort: Appears good as long as senior postdocs do no leave to quickly—the 3 year delay have been costly to them and our 12 graduate students

After six months of running—⅓ commissioning and ⅔ production data at 2×10^{12} protons/spill—SeaQuest will have scientifically interesting results representing an improvement on the E866 Statistics at $x\approx0.3$ and confirm decrease in dbar/ubar at large x.